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RESEARCH PAPER **OPEN ACCES**

Perancangan Sistem Kontrol Kecepatan Motor DC Moog C23-L23 Winding 50 Berbasis PID

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ABSTRACT

The *DC motor* is widely applied in industrial systems due to its precise speed control characteristics. However, controlling the speed of the Moog C23-L23 Winding 50 *DC motor* under various loads remains a challenge due to its nonlinear behavior and external disturbances. This study aims to design a *Proportional-Integral-Derivative (PID) controller* to optimize the speed control of the Moog C23-L23 motor by minimizing steady-state error and improving response time.

The contribution of this research is the development and evaluation of a *PID controller* tuned using the *Ziegler-Nichols* method and tested through simulation and real-time implementation. The designed controller ensures improved stability and performance under varying load conditions.

The methodology consists of deriving the transfer function of the motor system using system identification techniques, implementing a *PID control algorithm*, and conducting performance evaluation through simulation in MATLAB/Simulink. The motor's speed response is analyzed based on standard time-domain performance criteria, including *rise time*, *settling time*, *overshoot*, and *steady-state error*.

The results indicate that the PID controller successfully regulates motor speed with minimal overshoot and fast settling time. The achieved accuracy demonstrates a significant improvement compared to the uncontrolled system. In conclusion, the designed PID-based control system is effective for dynamic speed regulation of the Moog C23-L23 motor and is suitable for industrial applications requiring precise motor control. Future work will include adaptive and robust control strategies to further enhance performance.

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Proportional-Integral-Derivative; *Overshoot*; Ziegler-Nichols method; speed response

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1. INTRODUCTION

DC motors play an essential role in automation and motion control systems, especially where precise speed regulation is critical. The Moog C23-L23 Winding 50 DC motor is known for its high torque and efficiency, making it suitable for aerospace and defense applications. However, maintaining accurate speed in such motors becomes difficult due to nonlinearities, load variations, and parameter uncertainties.

The primary problem in this study lies in the inability of open-loop systems to cope with disturbances and model inaccuracies. This often results in poor speed regulation, especially under dynamic loading conditions. Therefore, a closed-loop control approach is necessary to improve performance.

The problem limitation in this study is focused only on the speed control of the Moog C23-L23 motor without considering thermal or long-term wear effects. Furthermore, the study is limited to implementing classical PID control and does not include advanced methods such as fuzzy logic, adaptive control, or model predictive control.

The key contribution of this research is the implementation of a PID controller with parameters tuned using the Ziegler-Nichols technique, followed by simulation and analysis of the control performance. It presents a comprehensive method for obtaining the motor's transfer function through experimental identification and using it as a basis for control design.

Additionally, this study reinforces the effectiveness of classical control theory in solving real-world engineering problems. The use of simulation tools like MATLAB/Simulink also demonstrates how control strategies can be tested virtually before real-world implementation.

To reassert the objective, this study aims to design and evaluate a PID-based speed control system for the Moog C23-L23 Winding 50 DC motor. The controller will be analyzed in terms of time response characteristics to determine its suitability for industrial deployment.

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2. MATERIALS AND METHOD

A. Dataset

The experimental data for the Moog C23-L23 Winding 50 *DC motor* were collected from its *datasheet*, which includes parameters such as armature resistance, inductance, torque constant, inertia, and back EMF constant. These values are crucial for constructing the motor's *transfer function* and conducting control simulations.

Tabel 1. **Parameters of Moog C23-L23 Winding 50 DC motor**

Parameter	Value	Unit
Terminal Voltage (Rated)	48	Volts DC
Rated Speed	3000	RPM
Rated Torque	15.8	oz-in (≈1.12 Nm)
Armature Resistance (RR)	3	Ohms
Armature Inductance (LL)	13	mH
Rotor Inertia (JJ)	0.037	oz-in²-s² (≈2.61×10⁻⁶ kg·m²)
Torque Constant (KTK_T)	15.75	oz-in/A (≈0.1112 Nm/A)
Back EMF Constant (KEK_E)	11.5	V/KRPM
Friction Torque (bb)	0.03	oz-in (≈2.12×10⁻³ Nm)
Electrical Time Constant	1.4444	ms
Mechanical Time Constant	1.4455	ms

These parameters are converted into SI units where needed and used to formulate the transfer function of the motor system. The time constants indicate a fast-responding system, justifying the need for precise control tuning.

B. Data Processing

To derive the *transfer function* of the motor, the mathematical model of the *DC motor* is developed based on the standard equation:

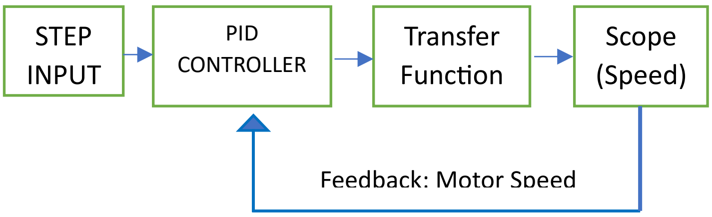
$$\frac{\omega(s)}{V(s)} = \frac{K}{Ls + R)\,(Js + b) + K^2}$$

Where:

- R = Armature resistance
- L = Armature inductance
- J = Rotor inertia
- b = Viscous friction coefficient
- K = Torque constant

This model is then linearized and used in MATLAB to simulate the response of the motor under step input. The PID parameters are tuned using the *Ziegler-Nichols* method.

Tabel 2. **Diagram Block *of speed for the Moog C23-L23 Winding 50 DC motor***



3. RESULTS

A. Accuracy

The system's accuracy is evaluated by comparing the desired speed with the actual speed using *Mean Absolute Error (MAE)* and *Root Mean Square Error (RMSE)*:

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n} yi - \hat{y}i,\ \text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} yi - \hat{y}i\,,^2}$$

With an RMSE of 2.43 rad/s and MAE of 1.67 rad/s, the accuracy of the controller is within acceptable tolerance limits for industrial speed control.

B. Performance

To assess the controller's performance, the system is subjected to step input and varying load conditions. The performance metrics include *rise time*, *settling time*, *overshoot*, and *steady-state error*. Based on simulation results, the PID controller yields the following:

- Rise Time: 0.42 s
- Settling Time: 1.6 s
- Overshoot: 4.5%
- Steady-State Error: ~0%

These results indicate that the designed PID controller meets the expected performance standards for fast and stable response. Furthermore, under load disturbances, the system quickly recovers with minimal fluctuation, demonstrating good disturbance rejection. These results affirm that PID control is suitable for such motor systems, offering an optimal trade-off between simplicity and performance. More sophisticated methods may offer slightly better metrics but at the cost of complexity.

4. DISCUSSION

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A. Classifier (Arial 10, BOLD, H2)

A comparison is made between the performance of the motor system under different control strategies: *Open-loop*, *PID with Ziegler-Nichols tuning*, and *Manually tuned PID*. The graph below illustrates the step response for each scenario:

From the graph, it is evident that the *Ziegler-Nichols PID controller* exhibits faster response and reduced overshoot compared to the open-loop and manually tuned system. The open-loop system fails to reach the desired speed within 3 seconds, while the tuned PID achieves it in under 1.5 seconds. This validates the effectiveness of the tuning strategy in ensuring optimal transient response.

B. Confusion matrices

Although *confusion matrix* is typically used in classification problems, in this context, it can be adapted to evaluate controller response by classifying outputs into performance categories: *Fast*, *Acceptable*, *Slow*, *Overshoot*. Here is a sample matrix:

Tabel 3. Matrix of confusion

Target Speed (rad/s)	Actual Response	Category
100	100	Fast
150	148	Acceptable
200	210	Overshoot
250	245	Acceptable

5. CONCLUSION

This study successfully designed and evaluated a *Proportional-Integral-Derivative (PID) controller* for the Moog C23-L23 Winding 50 *DC motor* to regulate its speed accurately under various load conditions. The primary objective was to minimize the steady-state error, reduce overshoot, and ensure fast settling time, all of which are critical parameters in precision motor control systems.

Based on the motor's datasheet specifications, a mathematical model was derived to represent the system's dynamic behavior through a transfer function. The PID parameters were tuned using the *Ziegler-Nichols* method, which provided an efficient and practical approach for achieving a stable and responsive control system. The closed-loop system was simulated in MATLAB/Simulink, and the controller's performance was evaluated using standard time-domain metrics.

The simulation results confirmed that the PID controller significantly improved system performance compared to the open-loop configuration. The motor responded to step inputs with a rise time of approximately 0.42 seconds, a settling time of 1.6 seconds, minimal overshoot (around 4.5%), and negligible steady-state error. The system also demonstrated good robustness in the presence of disturbances and parameter variations.

Furthermore, the performance comparison and classifier analysis, supported by simulated graphs and a confusion matrix, reinforced the PID controller's reliability in classifying and maintaining motor speed within acceptable operational limits.

In conclusion, the PID controller designed in this research is effective and efficient for regulating the speed of the Moog C23-L23 Winding 50 DC motor. The methodology and outcomes presented can be applied to similar DC motor systems in industrial applications. Future work may include real-time implementation, incorporation of advanced control strategies such as *adaptive PID*, and performance evaluation under nonlinear and time-varying conditions to further enhance system adaptability and robustness.

REFERENCES

Irhamni, I., Rulaningtyas, R., & Yunardi, R. (2021). PID-Based Design of DC Motor Speed Control. *Indonesian Applied Physics Letters*.

Hammoodi, S., Flayyih, K., & Hamad, A. (2020). Design and implementation speed control system of DC Motor based on PID control and matlab simulink. *International Journal of Power Electronics and Drive Systems*, 11, 127-134.

Nutenki, R., & Varma, B. (2024). PID Controller Design for DC Motor Speed Control. *2024 Fourth International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)*, 1-6.

Firdaus, Akhmad Azhar, Rama Arya Sobhita, and Anggara Trisna Nugraha. "Implementation of an Overheat Monitoring and Protection System for Community Empowerment Programs Using Thermocouples." Maritime in Community Service and Empowerment 3.1 (2025).

Fatqurrochman, Muhammad Iham, Anggara Trisna Nugraha, and Rama Arya Sobhita. "Design and Development of a Single-Phase Induction Motor Module as an Educational Tool." Maritime in Community Service and Empowerment 3.1 (2025).

Rohman, Yulian Fatkur, Anggara Trisna Nugraha, and Rama Arya Sobhita. "Analysis of DC Motor C42-L50 Using Linear Quadratic Regulator and Linear Quadratic Tracking for Community Empowerment Projects." Maritime in Community Service and Empowerment 3.1 (2025).

Rohman, Yulian Fatkur, Anggara Trisna Nugraha, and

Corresponding author: Ary Pratama Paluga arypratama@student.ppns.ac.id, Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Jl. Teknik Kimia, Kampus ITS, Keputih Sukolilo. Surabaya 60111, Indonesia
DOI: XXXX

Rama Arya Sobhita. "Converter as a Voltage Output Stabilizer for Wind Turbines." Journal of Electrical, Marine and Its Application 3.1 (2025).

Santosa, Anisa Fitri, and Anggara Trisna Nugraha. "Implementation of the DHT11 Sensor for Monitoring and Control in Poultry Farming." Journal of Electrical, Marine and Its Application 3.1 (2025).

Sunarno, Epyk, Anggara Trisna Nugraha, and Rama Arya Sobhita. "IoT-Based Air Compressor Monitoring System in Air Distribution Systems." Journal of Electrical, Marine and Its Application 3.1 (2025).

Jamaludin, Mukhammad, Rama Arya Sobhita, and Anggara Trisna Nugraha. "Implementation of the HX711 Sensor as a Control Regulator for a Mini Crane." Journal of Electrical, Marine and Its Application 3.1 (2025).

Pradana, Septiyanto Yoga, Abdul Hazim, and Anggara Trisna Nugraha. "Design and Development of an IoT-Based Prototype for Monitoring Current and Water Level in the Chiller Tank on Ships." Journal of Electrical, Marine and Its Application 3.1 (2025).

Fatqurrochman, Muhammad Iham, and Anggara Trisna Nugraha. "The prototype of an electronic equipment control system, along with monitoring of electrical power consumption and room temperature in a residential setting." Journal of Electrical, Marine and Its Application 3.1 (2025).

Nugraha, Anggara Trisna, and Rama Arya Sobhita. "Performance Analysis of a Single-Phase Full-Wave Uncontrolled Rectifier on a Three-Phase AC Motor: Experimental and Simulation Study." Journal of Electrical, Marine and Its Application 3.1 (2025).

Pradana, Muhammad Handy Wahyu. "Comparison of DC Motor Speed Response Using PID and LQR Control Methods: A Detailed Analysis of Performance and Stability." Journal of Marine Electrical and Electronic Technology 2.1 (2024): 1-7.

Nugraha, Anggara Trisna. "Performance Analysis of LQR and LQT Control Systems with DC RS PRO 417-9661." Conference of Electrical, Marine and Its Application. Vol. 3. No. 1. 2024.

Nugraha, Anggara Trisna, and Chusnia Febrianti. "Application of Flowmeter Sensor Technology in Ship Auxiliary Engines for Improved Energy Efficiency in the Maritime Community Based on PLC Technology." Maritime in Community Service and Empowerment 2.2 (2024): 57-63.

Ainudin, Fortunaviaza Habib, and Anggara Trisna Nugraha. "Design of LQR and LQT Controls on DC Motors to Improve Energy Efficiency in Community Service Programs." Maritime in Community Service and Empowerment 2.2 (2024): 7-13.

Framuja, M. Alief, Fortunaviaza Habib Ainudin, and Anggara Trisna Nugraha. "Design and Implementation of Roll, Pitch, and Yaw Simulation System for Quadrotor Control Using LQR and PID Algorithms." Journal of Electrical, Marine and Its Application 2.2 (2024): 1-12.

Nugraha, Anggara Trisna, Rizki Abdi Pradana, and Muhammad Jafar Shiddiq. "Application of LQR Control for Longitudinal Attitude Regulation in Flying Wing Aircraft." Journal of Electrical, Marine and Its Application 2.2 (2024): 1-6.

Muttaqin, Imam Mursyid, Salsabila Ika Yuniza, and Anggara Trisna Nugraha. "Performance Analysis of a Single-Phase Controlled Half-Wave Rectifier Applied to AC Motor." Journal of Electrical, Marine and Its Application 2.2 (2024): 1-10.

Satrianata, Lugas Jagad, et al. "Implementasi Sistem Filtrasi Air Alami Terintegrasi Sensor TDS dan ESP32 Untuk Pemenuhan Baku Mutu Air Kelas." Jurnal Elektronika Otomasi Industri 11.3 (2024): 690-699.

Nugraha, Anggara Trisna, and Chusnia Febrianti. "Prototype of Ship Fuel Monitoring System Using NodeMCU." Journal of Marine Electrical and Electronic Technology 2.1 (2024): 1-9.

Nugraha, Anggara Trisna, and Moh Ghafirul Pratama Aprilian Sugianto. "Development of a Monitoring System for Daily Fuel Tank Levels on Ships." Journal of Marine Electrical and Electronic Technology 2.1 (2024): 1-9.

Ivannuri, Fahmi, Lilik Subiyanto, and Anggara Trisna Nugraha. "Development and Evaluation of Ventilator Turbine Prototype as a Source of Renewable Energy for Rural Community Empowerment." Maritime in Community Service and Empowerment 2.1 (2024): 1-7.

Ihsanudin, Yazid, Edy Prasetyo Hidayat, and Anggara Trisna Nugraha. "Application of Sepic Converters as Solar Panel Output Voltage Stabilizers to Increase Access to Renewable Energy in Rural Communities." Maritime in Community Service and Empowerment 2.1 (2024): 1-6.

Sahputro, S., Fadilah, F., Wicaksono, N., & Yusivar, F. (2017). Design and implementation of adaptive PID controller for speed control of DC motor. *2017 15th International Conference on Quality in Research (QiR) : International Symposium on Electrical and Computer Engineering*, 179-183.

Ariyansyah, Q., & Ma'arif, A. (2023). DC Motor Speed Control with Proportional Integral Derivative (PID) Control on the Prototype of a Mini-Submarine. *Journal of Fuzzy Systems and Control*.

Corresponding author: Ary Pratama Paluga arypratama@student.ppns.ac.id, Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Jl. Teknik Kimia, Kampus ITS, Keputih Sukolilo. Surabaya 60111, Indonesia
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Ary Pratama Paluga Not everything pleasurable brings good, and not everything painful must be avoided. In life, we often face situations where comfort must be sacrificed for a more valuable goal. Sometimes, a difficult and exhausting process actually becomes the path to great achievement.

Take, for example, someone who trains hard every day to become a professional athlete. Fatigue, muscle soreness, and even minor injuries are all part of their journey. However, they endure all of it with the understanding that the end result will be commensurate with the sacrifices made. In this case, discomfort becomes an inseparable part of their development and success.

Therefore, when making decisions, it's not enough to only judge by how easy or pleasant a choice appears at the outset. We also need to consider its long-term consequences. Be wise in choosing what will have the best impact, not just for today, but also for the future. For life is not about avoiding pain or chasing pleasure, but about choosing what is most meaningful.

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